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Stochastic Model Predictive Control with Applications in Smart Energy Systems

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Abstract: In response to growing concerns related to environmental issues, limited resources and security of supply, the energy industry is changing. One of the most significant developments has been the penetration of renewable energy sources. In Denmark, the share of wind power generation is expected to cover more than 50% of the total consumption by 2050.

Energy systems based on significant amounts of renewable energy sources are subject to uncertainties. To accommodate the need for model predictive control (MPC) of such systems, the effect of the stochastic effects on the constraints must be accounted for. In conventional MPC, the stochastic effects on the constraints is handled by constraint back-off and the MPC problem can still be solved by solution of either a linear program or a quadratic program. Treating the constraints as probabilistic constraints provides a more systematic approach to handle the stochastic effects on constraints. In this formulation, the MPC may be represented by a chance constrained mathematical program. The chance constraints allow a direct tradeoff between a certain (low) frequency of violating the constraints and a performance function (e.g. an economic loss function). This is convenient for energy systems, since some constraints are very important to satisfy with a high probability, whereas violation of others are less prone to have a large economic penalty.

In MPC applications the control action is obtained by solving an optimization problem at each sampling instant. To make the controller applicable in real-time efficient and reliable algorithms are required. If the uncertainty is assumed to be Gaussian, the optimization problems associated with chance constrained (linear) MPC can be expressed as second order cone programming (SOCP) problems. In this paper, we show that tailored interior point algorithms are well suited to handle this type of problems. Namely, by utilizing structure-exploiting methods, we implement a special-purpose solver for control of smart energy systems. The solver is compared against general-purpose implementations. As a case study, we consider a system consisting of fuel-fired thermal power plants, wind farms and electric vehicles.
